National Aeronautics and Space Administration

TIRS-The Thermal Infrared Sensor on the Landsat Data Continuity Mission

data continuity mission

Landsat Science Team Meeting

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Real Credit Goes to the TIRS Instrument Team

LDCM LANDSAT

TIRS High-level Overview

- TIRS is a two channel thermal imager providing data continuity for the Landsat thermal band.
  - Pushbroom imager developed by NASA/Goddard Space Flight Center
  - TIRS operates in concert with, but independently of, OLI.

- TIRS will produce radiometrically calibrated, geo-located thermal image data
  - TIRS will deliver algorithms and parameters necessary to evaluate data and produce required outputs
  - Final scene data generated as part of the Data Processing and Archive Segment at the United States Geological Survey/ Earth Resources Observation and Science (EROS) facility in Sioux Falls, South Dakota.
  - USGS responsible for operational algorithms
  - OLI and TIRS data will be merged into a single data stream.

- TIRS was delivered in February 2012.
  - The TIRS delivery schedule was a significant driver of the overall TIRS development.

TIRS Instrument Overview

- 2 channel (10.6-11.2 um and 11.5-12.5 um) thermal imaging instrument
- Quantum Well Infrared Photodetector (QWIP) detector/FPA
- <120 m Ground Sample Distance (100 m nominal)
- 185 km ground swath (15º field of view)
- Operating cadence: 70 frames per second
- Precision scene select mirror to select between nadir view, onboard variable temperature blackbody and space view
- Passively cooled telescope assembly operating at 185K (nominal)
- Actively cooled (crycooler) FPA operating at ≤43K
- Thermal stability key to radiometric stability (NEΔT < 0.4 K @ 300 K)

TIRS Operational and Data Sequence

- Point SSM to onboard blackbody calibrator (OBC) – take 1 minute of data
  - Provides measure of instrument performance for known target

- Point SSM to deep space view – take 1 minute of data
  - Provides measure of instrument background

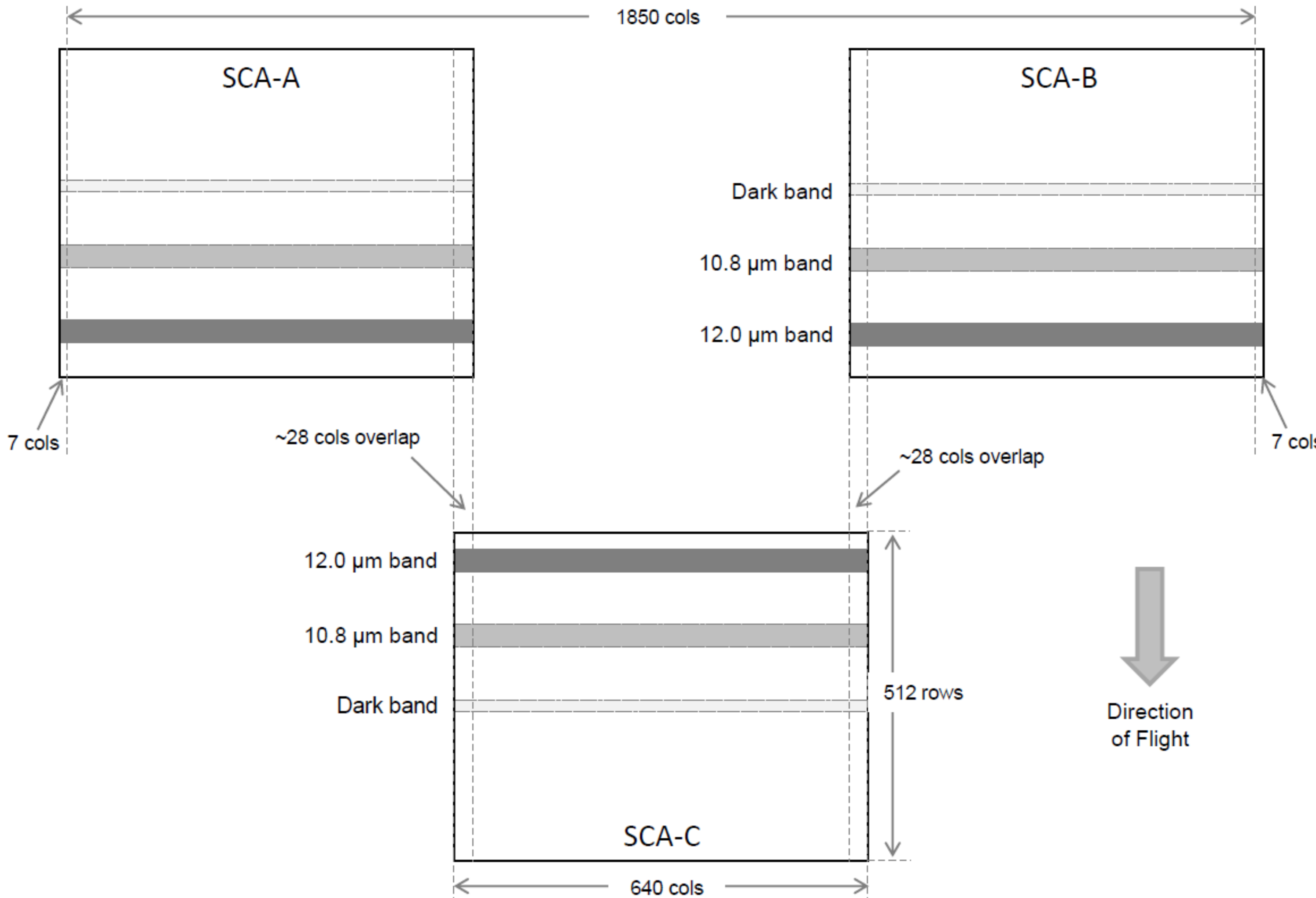
- Point SSM nadir toward Earth – take up to 77 WRS2 images

- Subtract background

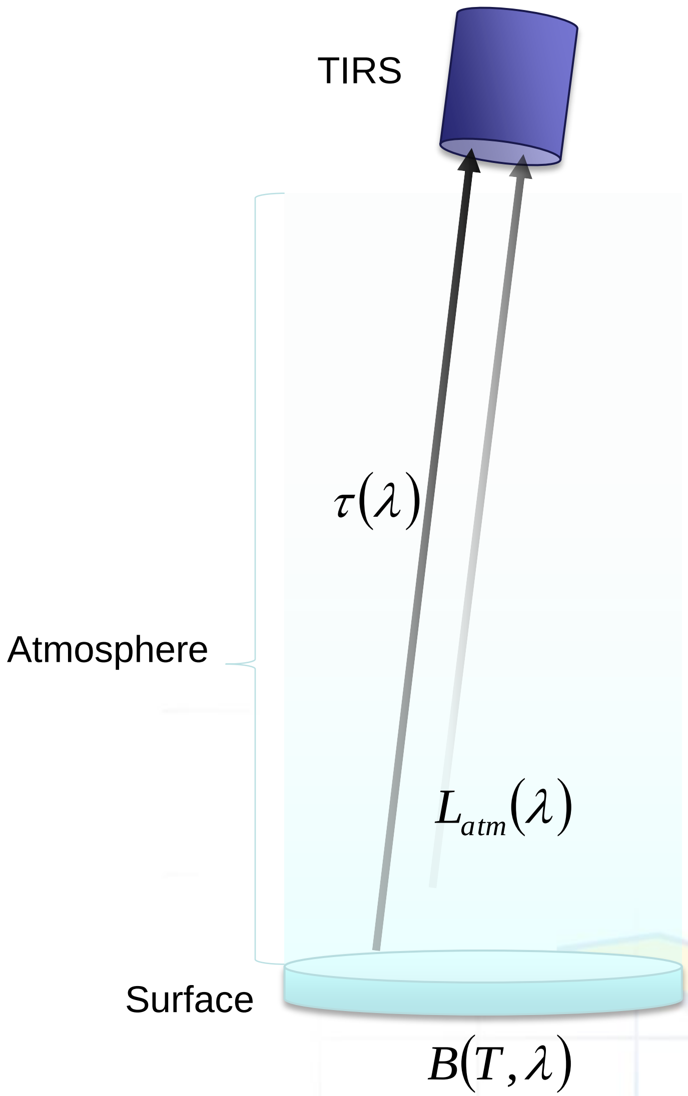
- 2 rows of data taken in each channel and in dark area
  - Combined into a single effective row on the ground
    - Generally, all pixels in each row are good.
  - Dark only used if detector temperature is not stable

- Several additional calibration modes
  - Integration time sweeps
  - OBC temperature change
  - Lunar views
  - Side slither (scan 90º relative to normal direction)

TIRS Focal Plane Layout (3 QWIPs)

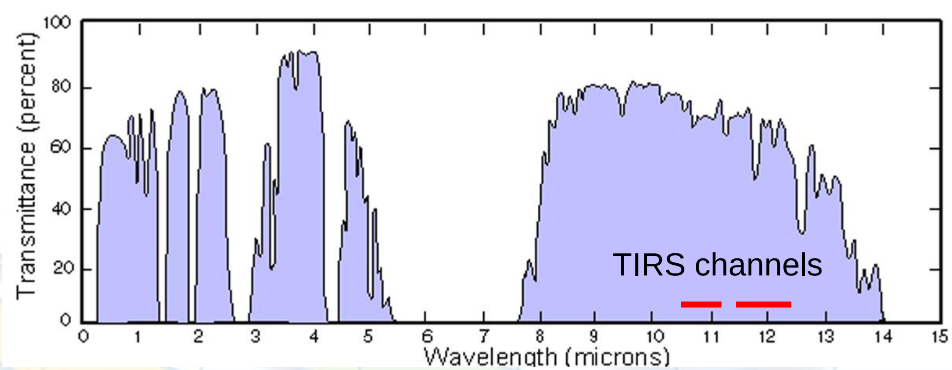


Radiance Detected by TIRS from Surface and Atmosphere

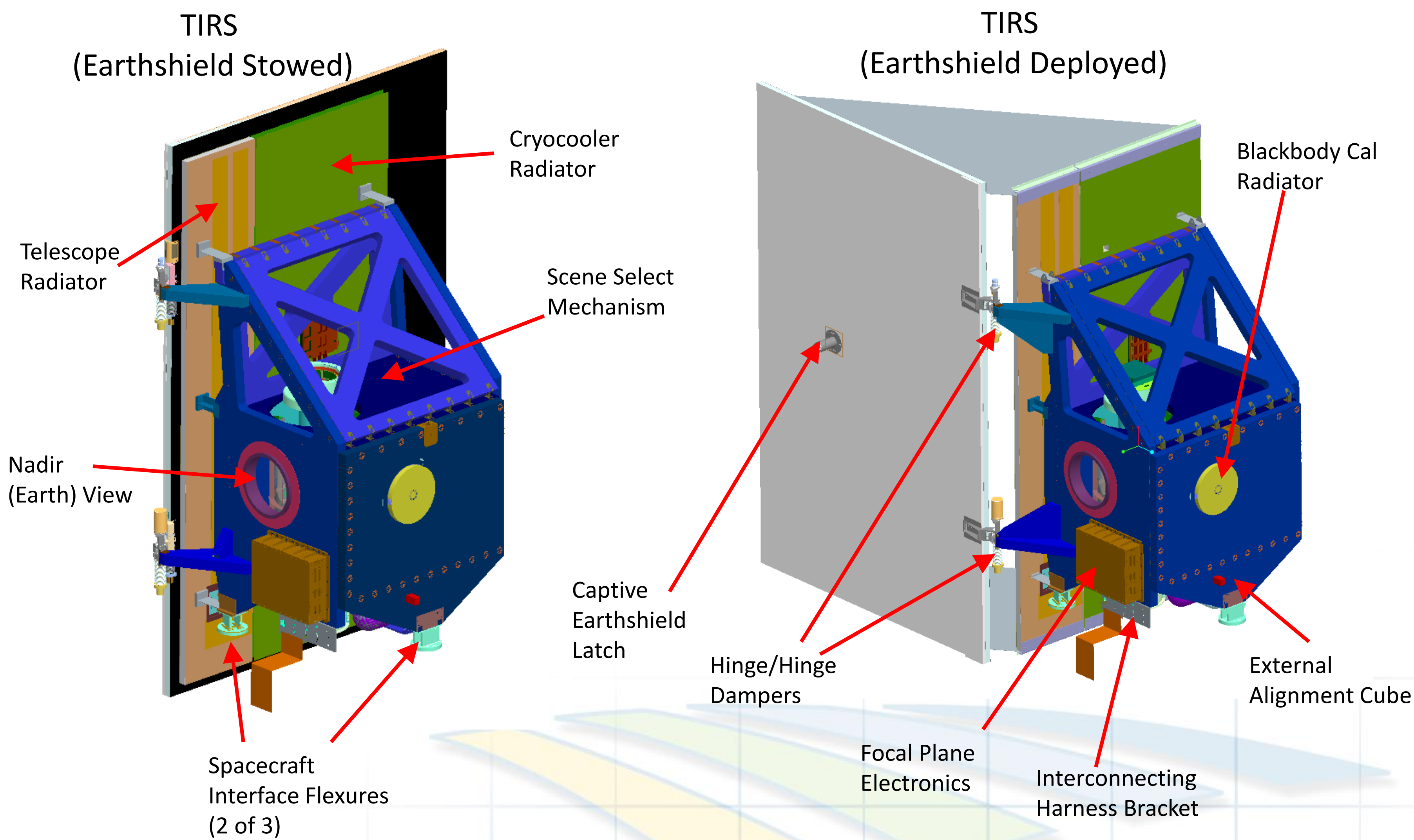


$$L_s = \frac{\int \left(B(T,\lambda)\cdot \tau(\lambda) + L_{atm}(\lambda)\right)\cdot R'(\lambda)\cdot d\lambda}{\int R'(\lambda)\cdot d\lambda}$$

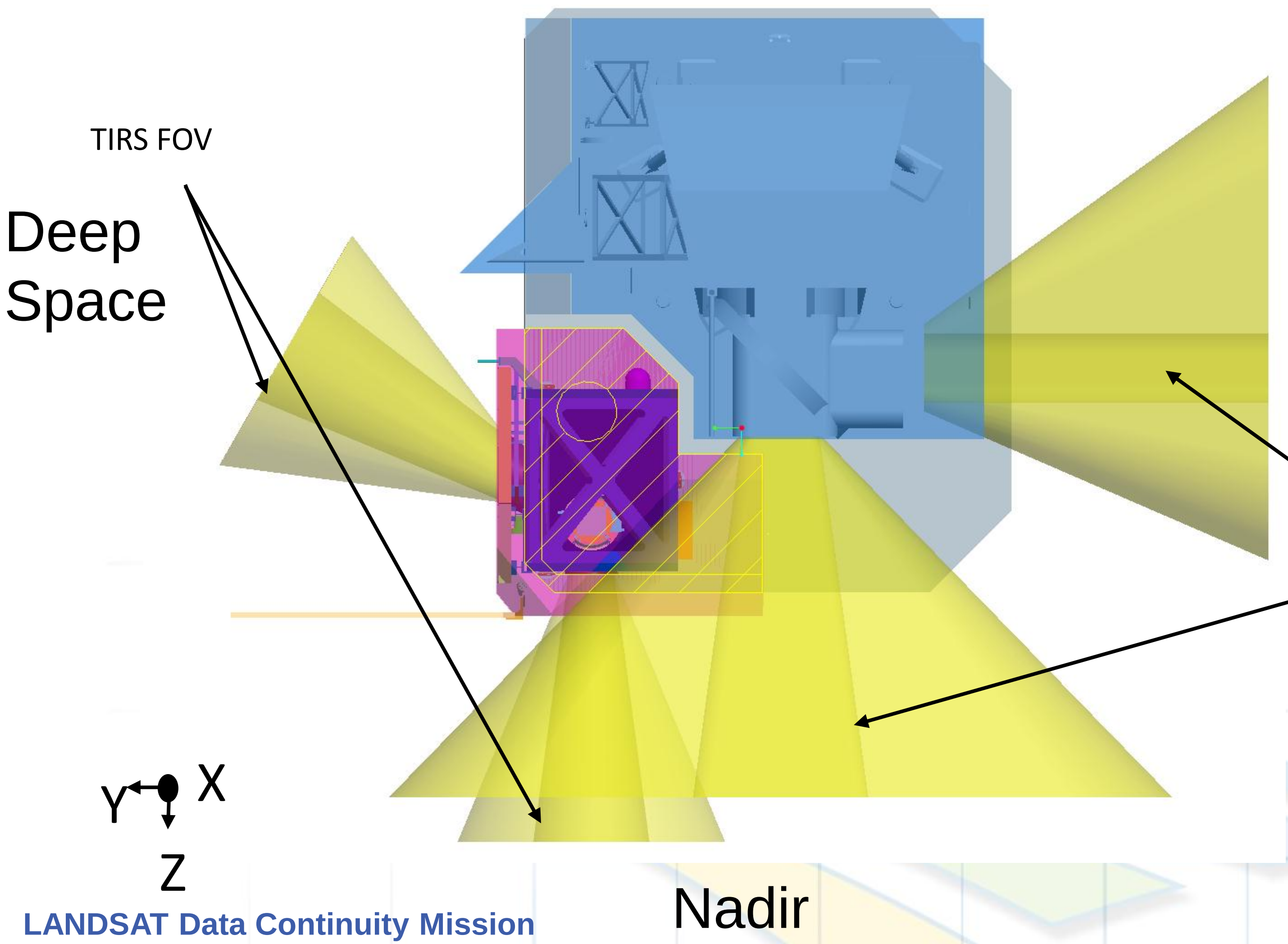
- $B(T,\lambda)$ • Emitted and reflected surface radiance
- $\tau(\lambda)$ • Transmission of atmosphere
- $L_{atm}(\lambda)$ • Emitted and scattered radiance of atmosphere
- $R'(\lambda)$ • Spectral response of detector
- L_s • Detector integrated radiance



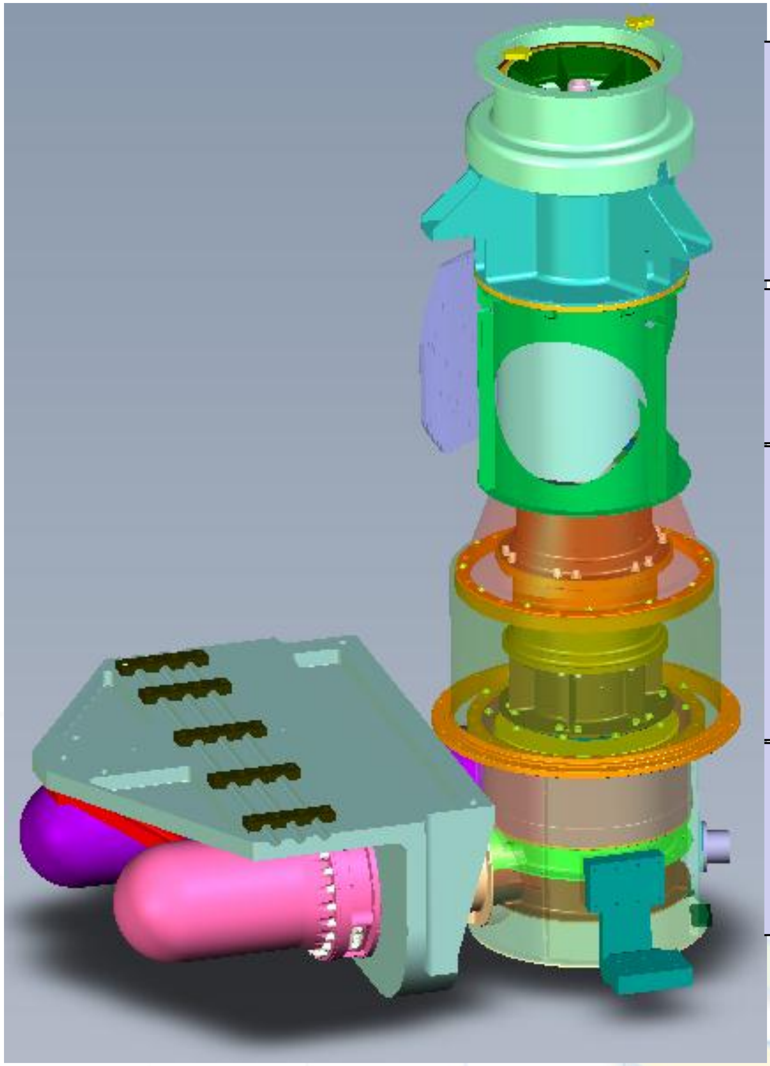
TIRS Assembly Overview



TIRS Instrument FOVs



Thermal Design Provides Required Stability



Thermal Zones:
Warm End
-Scene Select Mechanism
-Scene Select Mirror & Baffles (≤293K)
-Stability ±1K (35 sec)
-Stability ±2K (44Min)

-Blackbody Calibrator (270 to 320K)
-Stability ±0.1K (35 sec)

Cold End

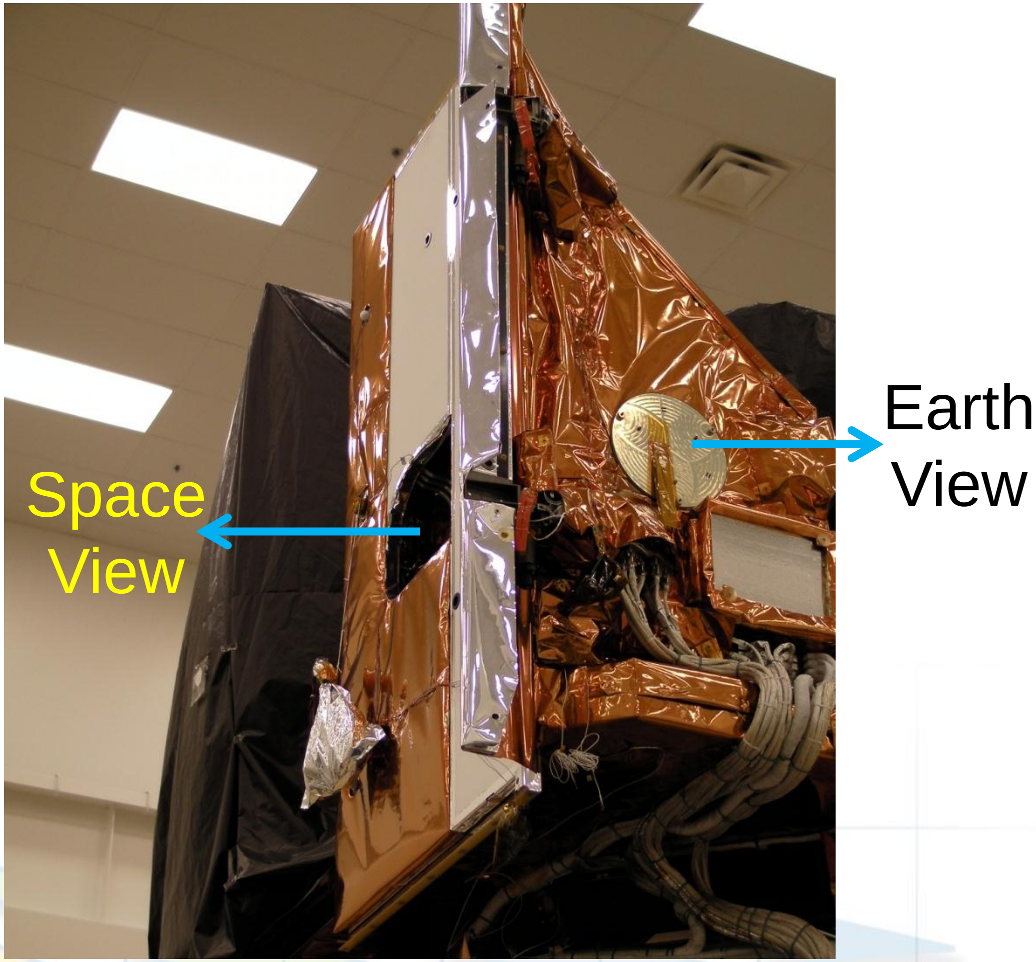
-Tel Stage: Tel Assembly (185K)
-Stability ±0.1K (35 sec)
-Stability ±0.25K (44Min)

-Warm Stage: FPA Shroud (≤88K)

-Cold Stage: FPA (≤43K)
-Stability ±0.01K (35 sec)
-Stability ±0.02K (44 min)

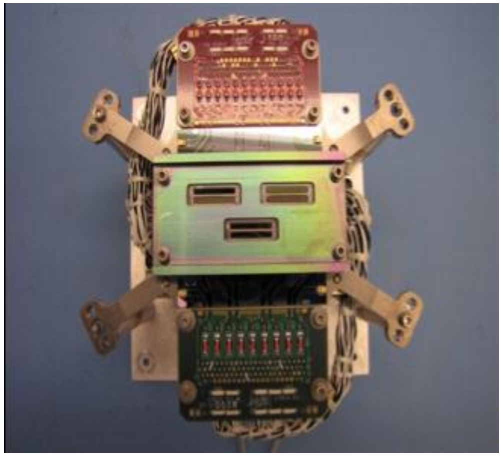
HERE'S TIRS

Leaving Goddard Space Flight Center

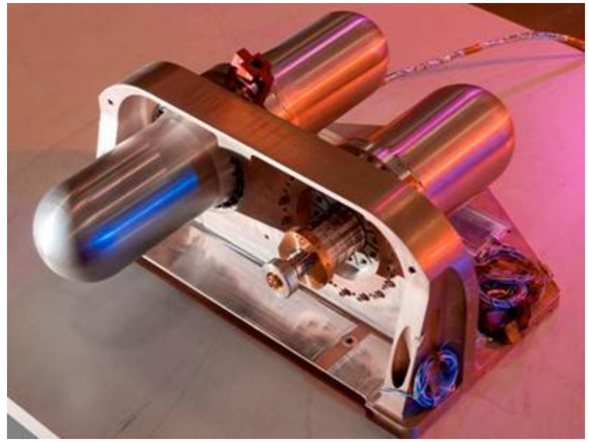


On the Spacecraft, Showing Views

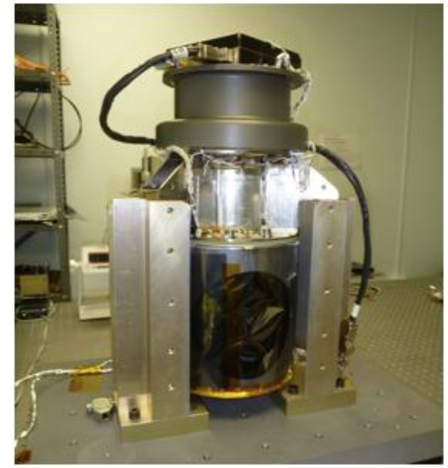
TIRS: GREATER THAN THE SUM OF ITS IMPRESSIVE PARTS



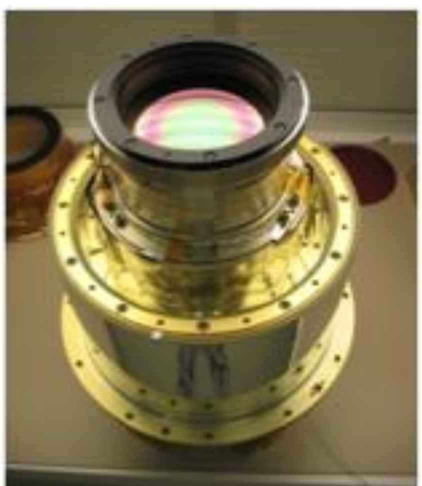
QWIP Focal Plane: Makes 2-channel Images



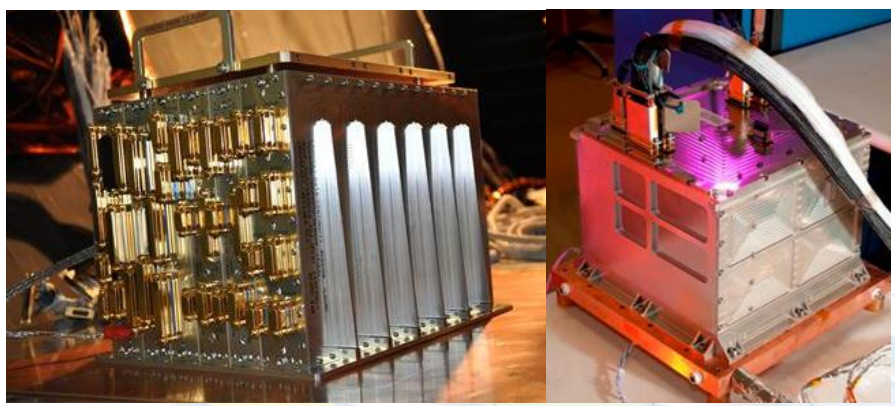
Cryocooler: Cools Focal Plane to -385º F



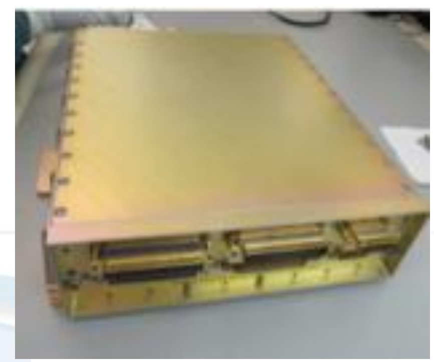
Scene Select Mechanism: Points View to 0.0006º



Telescope: Focuses IR Light



Main Electronics and Cryocooler Electronics: Control operations and Save Data



Focal Plane Electronics: Reads Images

Pre-launch Performance Verification

- Most performance metrics meet or exceed requirements
  - Spatial shape parameters slightly out of range
  - Minor exceedence in two spectral characteristics
    - DIRSIG simulations indicate non-uniformity effect < 0.1%
  - Pointing knowledge is slightly out of range
    - 36 μrad instead of 27 μrad

- None of the above exceedences will have a science impact
  - LDCM cal/val team has concurred on waivers or CCRs where appropriate

- NIST radiometric traceability calibration of flood source indicates excellent agreement (~0.3%) with a 0.992 emissivity blackbody
  - After full implementation of cal routine, expect overall calibration accuracy better than 1%
  - On-orbit vicarious Earth calibration will also provide verification

Slight Residual Scattering Risk

- TVAC2 measurements show 5% scattering effect in some areas which exceeds allowance
  - Measurement and models indicate this is almost certainly caused by back reflectance into the cal GSE
    - Exacerbated by necessity of operating SSM at off-nadir angles to reach beyond edge of focal plane
      - Not done in flight
      - Nadir SSM measurements show < 0.4% scattering
  - In the highly unlikely event that in-flight performance shows scattering is in TIRS, data in hand is sufficient to develop numerical correction algorithms

Pre-launch Performance Reports

- TIRS-IS-RPT-0089 Calibration Report
- TIRS-IS-RPT-0090 Spectral Report
- TIRS-IS-RPT-0091 Radiometry Report
- TIRS-IS-RPT-0092 Spatial Report
- TIRS-IS-RPT-0093 Scatter Report
- TIRS-IS-RPT-0094 Bright target recovery Report
- TIRS-IS-RPT-0095 Radiometric Calibration Report
- TIRS-IS-RPT-0096 Radiometric Precision Report
- TIRS-IS-RPT-0097 Noise Report
- TIRS-IS-RPT-0098 Pointing Report
- TIRS-IS-RPT-0099 Onboard Blackbody Report

- Final Access to these may be limited by ITAR etc.
  - Method to make necessary information available in process

240 K Noise Performance Exceeds Requirements

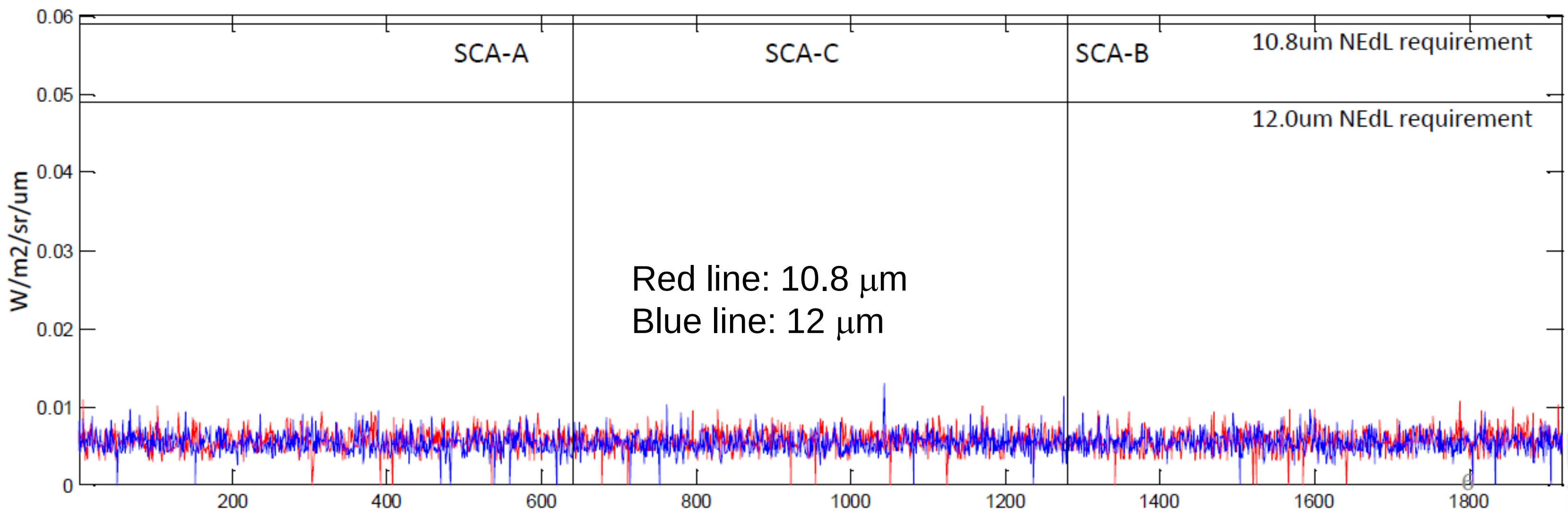
Procedure:

- 10 frames of Flood source @ 240K
- Linearize 10 Flood frames
- Subtract linearized background (deep space collect)
- Convert each of the 10 frames to radiance
- Calculate standard deviation of the 10 frames per pixel
- Take NEdL as the st. dev. over the science row

Result:

10.8um: NEdL = **0.005619** W/m2/sr/um (req. is 0.059 W/m2/sr/um) – NEdT approx. 0.039K (Req. 0.80K)

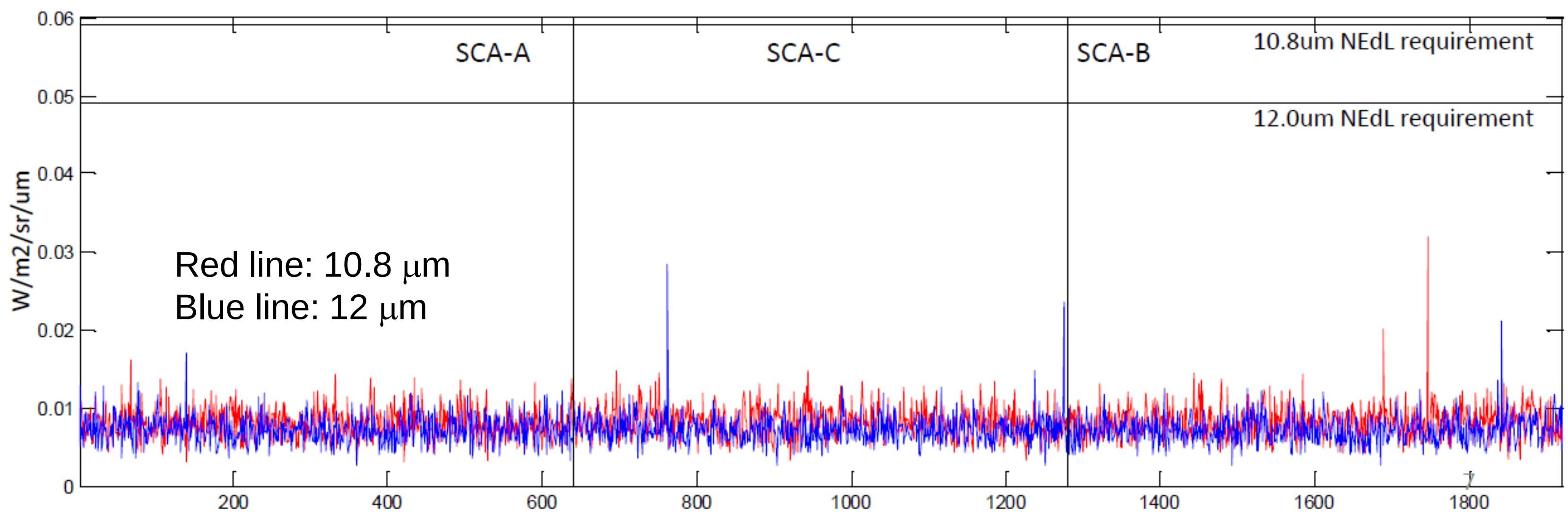
12.0 um: NEdL = **0.005325** W/m2/sr/um (req. is 0.049 W/m2/sr/um) – NEdT approx. 0.044K (Req. 0.71K)



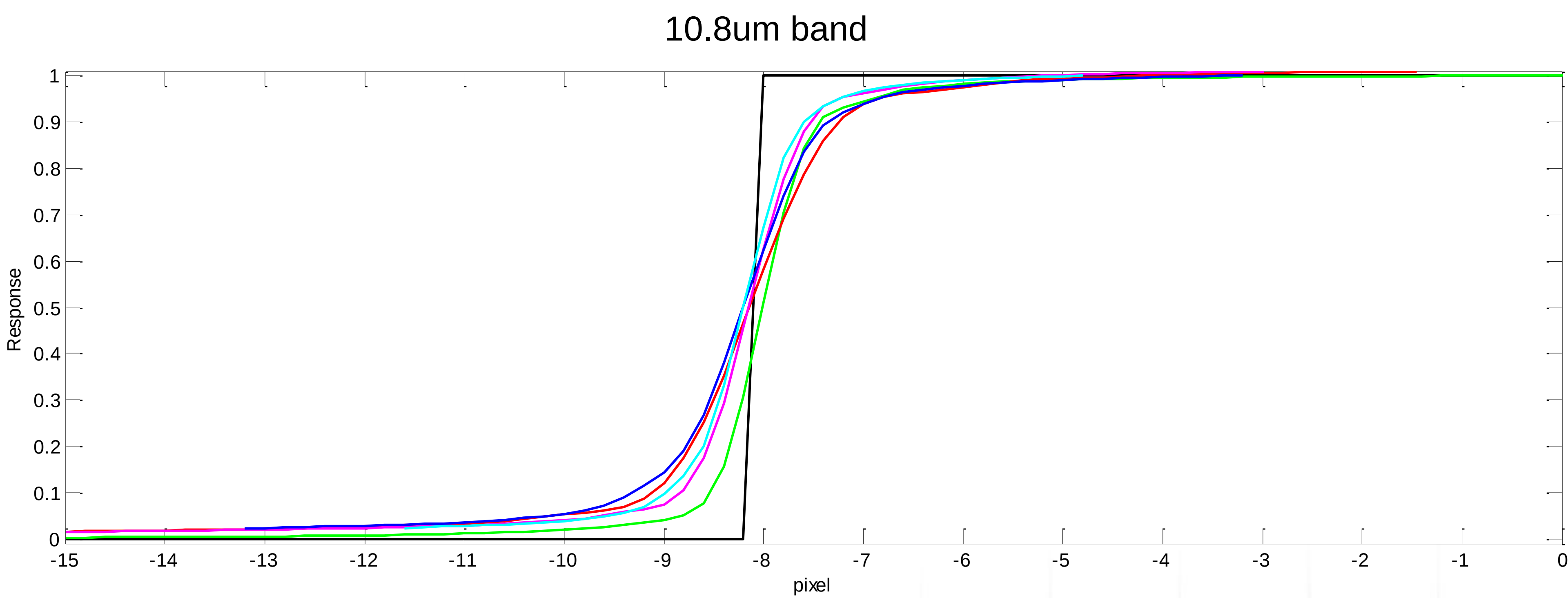
360 K Noise Performance Exceeds Requirements

Procedure:
- 10 frames of Flood source @ 360K
- Linearize 10 Flood frames
- Subtract linearized background (deep space collect)
- Convert each of the 10 frames to radiance
- Calculate standard deviation of the 10 frames per pixel
- Take NEdL as the st. dev. over the science row

Result:
10.8um: NEdL = **0.008096** W/m2/sr/um (req. is 0.059 W/m2/sr/um) – NEdT approx. 0.057 K (Req. 0.27K)
12.0 um: NEdL = **0.007226** W/m2/sr/um (req. is 0.049 W/m2/sr/um) – NEdT approx. 0.060 K (Req. 0.29K)



Summary of spatial shapes for various assumptions:10.8 μm



- Perfect 16-pix circle (black)
- Modeled Edge derived from PSF determined from WFE (green)
- Measured Edge (blue)
- Modeled Edge based on composite PSF for measured (red)
- Edge that exceeds requirements (cyan)
- Modeled Edge based on composite PSF for required (magenta)

	RER [/m]	Edge Extent [m]
Wavefront derived PSF:	0.0100	111.15
Measure derived PSF:	0.0058	187.95
Required derived PSF:	0.0084	131.26
Requirement:	> 0.007	< 150

Spatial shape exceedences will not significantly impact science

- As seen from previous charts measured shape is not significantly different than required
- Measured shape does not take possible GSE effects into account and is a worst case
  - Lunar observations will be used to verify shapes
- DIRSIG simulations using derived PSFs show that only a few percent difference in radiance is expected between measured edge response and required edge response
  - True even for unphysical case of 60 K change in temperature in a single pixel
  - Effect much less that 1% for typical thermal gradients

Performance Summary

- TIRS performance remained constant through environmental testing
- Most performance parameters meet or exceed requirements
- Exceedences do not affect science performance
  - Expect some of the exceedences are in part due to cal GSE
- Appropriate waivers and CCRs have been agreed to in principle by cal/val team and Project Scientist
  - Formal process is ongoing
- If necessary, analytical corrections are possible using characterization data in hand.
- Fully expect TIRS data to knock your socks off.

IT TAKES A GREAT TEAM

WITH INDUSTRIAL PARTNERS ACROSS THE NATION